NATIONAL ACTION PLAN ON BREAST CANCER
Breast Cancer Etiology Working Group
Workshop on Medical Ionizing Radiation and Human Breast Cancer
November 17 and 18, 1997

Summary of Presentations

BACKGROUND

The 1½-day Workshop on Medical Ionizing Radiation and Human Breast Cancer, held November 17 and 18 at the Loews L'Enfant Plaza Hotel in Washington, DC, was sponsored by the National Action Plan on Breast Cancer (NAPBC), a public/private partnership formed to stimulate rapid progress in eradicating breast cancer. The workshop was co-chaired by Barbara Balaban from the West Islip Breast Cancer Coalition and Charles Land from the National Cancer Institute's Radiation Epidemiology Branch, Division of Cancer Epidemiology and Genetics.

The goal of the Breast Cancer Etiology Working Group, one of the six working groups that compose the NAPBC, is to expand the scope of biomedical, epidemiological, and behavioral research activities related to the etiology of breast cancer. To that end, the Etiology Working Group established subgroups, one of which focuses on radiation and electromagnetic fields.

The Radiation and Electromagnetic Fields Subgroup convened this workshop to bring together scientists, advocates, and other interested parties to make recommendations for an appropriate national response to concerns about the effects of the uses of medical ionizing radiation on breast cancer. At the workshop, participants discussed what is known and suspected about the effects of medical ionizing radiation. Presentations, by advocates, scientists, researchers, and a lawyer/advocate included an overview of breast cancer epidemiology, the epidemiology of radiation-related breast cancer, genetic susceptibility to radiation-related breast cancer, an overview of experimental research, radiation protection in medical radiography and breast cancer, the experience of the Food and Drug Administration with the Mammography Quality Standards Act (MQSA), legal issues, medical and consumer education, responsible informed consent, and reducing ionizing radiation exposure. After each presentation, participants had the opportunity to ask questions. The workshop also included two general discussion sessions and a concluding roundtable discussion in which participants developed recommendations for future research, education, and policy.

WELCOME
Susan Sieber

Dr. Sieber, Co-Chair of the Etiology Working Group, welcomed participants to the workshop and presented a brief history of the NAPBC and of the Etiology Working Group. She also gave an overview of the Working Group's activities.

INTRODUCTION
Barbara J. Balaban

Ms. Balaban, workshop co-chair, observed that a common misperception is that there is no known cause of breast cancer. Although there are many suspected causes, there is one known cause: ionizing radiation (IR). Millions of dollars have been spent to investigate the unknown causes, but little has been done to reduce risks associated with the one cause that is known. Exposure to medical radiation is more likely to result in breast cancer than in any other cancer, and 50 percent of radiation from nuclear medicine affects the breast. Women exposed to radiation before the age of 20 develop breast cancer more often as those who have not been exposed so early.

The issue is not whether the medical use of x-rays accounts for a particular percentage of breast cancer; the issue is that exposure to cancer-causing radiation is occurring in doctors' offices. The use of medical x-rays has increased tremendously. Although research must continue, there are immediate avenues of remediation that can be initiated. Ms. Balaban did not advocate eliminating diagnostic and treatment x-rays but recommended exploring methods to reduce consumers' exposure to medical x-rays, such as using lower doses, decreasing frequency of administration, improving equipment, and raising public awareness of risks. Even in life-saving procedures, patients and doctors should consider whether the radiation dose could be responsibly reduced.

Reducing consumers' exposure to radiation in medical diagnosis and treatment is possible and necessary. Ms. Balaban asked attendees to consider the following questions during presentations at the workshop: What is medically necessary exposure? What can be done to reduce that exposure; for example, can exposure for a particular diagnostic procedure be lowered? How does the doctor or patient know what dose level is being emitted and how to track x-ray exposure over time? What changes should equipment manufacturers implement? What is the acceptable lifetime level of radiation exposure? What do physicians and consumers need to know, and what are the best methods to educate them?

Charles E. Land

Dr. Land, workshop co-chair, reviewed the agenda and explained that considerable time had been allowed for discussion because it was a vital component of the workshop. He also asked the scientific experts, to the extent possible, to address the concerns expressed by the advocates.

ADVOCATES' PERSPECTIVES

Nancy Evans

Ms. Evans, a board member of The Breast Cancer Fund and Breast Cancer Action and a breast cancer survivor, shared her history of radiation exposure, including dental and chest x-rays, annual mammograms, a computed tomography scan of her sinuses, and radiation treatment following a lumpectomy. She expressed concern that medical radiation might have contributed to the development of her breast cancer.

Ms. Evans proposed five steps to reduce exposure to medical IR:

- Tell the truth about the risks and benefits of radiation. The public should be aware that radiation is a proven cause of breast cancer, that there is no safe dose of radiation, and that radiation exposure is cumulative over a lifetime. Mammography is not a risk-free procedure; it exposes people to radiation that may cause cancer, especially in young women. Likewise, adjuvant radiation treatment following lumpectomy may not be a benign procedure, and new technology in breast cancer detection actually may increase radiation exposure.

- Move beyond mammography. Make it a priority to develop an early detection method for breast cancer that does not involve radiation or compression of the breast by funding research on blood markers, transillumination, breast biophysical examination, and other alternatives to mammography.

- Educate doctors about the risks of medical radiation. Doctors who refer patients for radiological procedures and the staff of radiological facilities should know the standard radiation dose of specific procedures.

- Continue to improve radiological equipment and techniques so that the necessary diagnostic information can be obtained with a lower total dose of radiation. For example, in 1972, the planned radiation dosage for women in the Breast Cancer Detection and Demonstration Project was 2 rads; today it is 0.2.

- Establish a method similar to keeping an immunization record to document an individual's lifetime exposure history.

Ms. Evans concluded by commenting that, unless exposure is reduced, women will continue to die from cancers induced by medical radiation.

Ellen Crowley

Ms. Crowley, a patient activist with the Women's Community Cancer Project of Cambridge/Boston, described the project, her family history with cancer, her radiation history, and her growing awareness of the risks of radiation. The Women's Community Cancer Project, which began in the late 1980s as a feminist collective group, addresses all types of cancer. The project has conducted research and published fact sheets to disseminate information about cancer to the public. Project members are concerned particularly about the environmental impact of carcinogens—such as radiation and pesticides—on the cancer process, because they believe that low-level carcinogens can accumulate and potentiate each other to increase cancer risk.

Ms. Crowley presented statistics on cancer and on medical IR. For example, in the 1960s, ecologist Rachel Carson predicted that cancer would develop in one in four people. Currently the disease develops in one in three women and one in two men. This increase is not due to the aging of the population; since 1950, there has been a 50 percent increase in cancers standardized by age. Although radiation is a known mutagen and carcinogen, radiation exposure is extensive in the United States.

Ms. Crowley discussed her personal and extensive family history with breast cancer. She also reviewed her radiation exposure history, including mammograms beginning in her 20s because of her family history. The mammograms missed her first breast cancer 10 years ago and her second in the other breast 1 year ago.

Ms. Crowley stated that she is not against medical IR, but she believes that consumers must be informed that radiation is dangerous. She called attention to an example of misleading consumer education material, a booklet describing nuclear radiation as benign. Ms. Crowley also observed that there is a need for a more explicit informed consent process for radiological procedures. In addition, she suggested that hospitals presently have no financial incentive to reduce their use of x-rays; hospitals that are invested heavily in x-ray equipment continue using them to bring in revenue.

Sharon Batt

Ms. Batt is the director of policy and research at Breast Cancer Action of Montreal. She described how a breast cancer diagnosis changed her attitude toward medical ionizing radiation from

indifference to concern. After she learned that radiation had been a known cause of breast cancer since 1965, when the first cases were diagnosed among atomic bomb survivors (Kushner, 1984), she became much more discriminating about undergoing radiographic tests. She also realized that she had no records of radiographic tests performed earlier in her life.

Ms. Batt discussed three areas related to medicine in Canada that differ from their American counterparts: the public health care system, mammography screening programs, and the legal system in regard to malpractice suits. Canada, which has the second highest per capita rate of breast cancer in the world after the United States, guarantees everyone access to basic medical health care; however, there is less access to specialized, highly technological procedures, including many radiographic tests (Morgan, 1993), than in the United States. For example, as of October 1992, the United States had over two thousand MRI scanners. Canada, with one-tenth the U.S. population, had only 22. According to Morgan, access to high-technology procedures in the United States is determined more by ability to pay than by medical need; in Canada, hospitals are expected to prioritize patient access to expensive procedures by need. In addition, government approval is necessary for a Canadian hospital to purchase expensive equipment with high, long-term operating expenses (Rachlis and Kuschner, 1994). Provincial health departments now are reforming their systems to contain costs, and x-rays are among the targets.

Mammography screening programs in Canada are organized by province and are the main focus of Canada's official strategy for fighting breast cancer. The government screening programs are highly regulated, screening is limited to the target population of women aged 50 to 69, the frequency of screening is controlled (usually every 2 years), and rigorous procedures are in place to monitor equipment and train technicians. Ms. Batt supports these programs but is concerned that the country still has not developed a comprehensive approach to prevention.

Because the legal system has structural features that discourage litigation and large settlements, medical malpractice suits in Canada are much less common than in the United States, and injury settlements are much smaller. While defensive use of medical tests therefore may be less prevalent in Canada than in the United States, fear of lawsuits nonetheless is recognized as a factor in Canadian medical practice.

Ms. Batt discussed similarities in breast cancer prevention advocacy in Canada and the United States, pointing out that in both countries, women have had to bypass traditional sources of information to learn that radiation has been a known cause of breast cancer for 30 years. Advocates from both countries share several concerns: they want to see prevention made a priority and differentiated from early detection, they want the public to be told about the risks of medical IR procedures, they want to be involved in making decisions about when and how much radiation is acceptable, and they want their health systems to value safety margins over profit margins.

Two events have advanced radiation protection with respect to breast cancer: breast cancer among atomic bomb survivors drew attention to the dangers of low-level radiation, and the excessive radiation exposure in the Breast Cancer Detection Demonstration Project prompted a reduction in radiation dosage. This pattern is crisis management. Ms. Batt concluded that current efforts to address cancer and radiation should act on what is already known.

OVERVIEW OF BREAST CANCER EPIDEMIOLOGY
Marilie D. Gammon

Dr. Gammon's presentation focused on the incidence of breast cancer and on determining who develops the disease, rather than survivorship or mortality; epidemiologists study incidence, or new cases of disease, rather than mortality when trying to determine what causes breast cancer.

Although breast cancer epidemiology evolved mainly in the second half of this century, physicians have noted for centuries that nuns have a higher incidence of breast cancer. One of the first epidemiologic breast cancer studies was published in the 1920s, but traditional epidemiologic studies did not appear until the 1950s. More detailed epidemiologic studies were conducted in the 1970s, and currently, epidemiologic research provides comprehensive data on breast cancer incidence.

According to American Cancer Society data, approximately 110 per 100,000 women develop breast cancer; this statistic translates into 180,000 new breast cancer cases this year. The mortality rate is 27.2 per 100,000, or approximately 46,000 deaths this year.

Surveillance, Epidemiology, and End Results (SEER) data indicate that the majority of breast cancer cases (75 to 80 percent) occurs in women over age 50. Although incidence rates for breast cancer in white and black women have remained steady since the late 1980s, for women over age 50, incidence rates climbed steadily between 1973 and 1989. White women over age 50 have the highest rate of breast cancer incidence in the United States.

Dr. Gammon presented a graph of the incidence of newly developed breast cancer by age, comparing Connecticut (as representative of the United States) and Japan. Age is the most significant risk factor for breast cancer in the United States. In age-specific annual breast cancer rates, breast cancer incidence climbs after age 50 in the United States, whereas it decreases in Japan after age 50. When Japanese women come to the United States, however, breast cancer incidence among succeeding generations of Japanese Americans reaches that of U.S. women, indicating that genetic differences between the two populations do not account for the geographic disparity in breast cancer incidence.

Established reproductive risk factors for breast cancer include nulliparity, early age at menarche, late age at menopause, and late age at birth of first child. Reproductive risk factors have been studied intensively because they help scientists understand the underlying biology of breast cancer. As a result of these studies, researchers have found that endogenous estrogens increase the risk of breast cancer. Serum levels of estrogen in postmenopausal women with breast cancer have been found to be higher than in those without breast cancer (Toniolo et al., 1995; Dorgan et al, 1996).

Studies of reproductive factors suggest that the timing of exposure to carcinogens is critical. The time between exposure and disease is estimated as 15 to 30 years, and the period between menarche and first birth may be the most critical for exposure to a carcinogenic risk (Colditz and Frazier, 1995). Other established breast cancer risk factors include a family history of breast cancer, personal history of breast cancer, benign breast disease, postmenopausal obesity, alcohol use, and high-dose levels of radiation.

Suspected risk factors include never having lactated, use of oral contraceptives, use of hormone replacement therapy for more than 10 years, and lack of exercise. Dr. Gammon's review of published studies on exercise and breast cancer will be published in the *Journal of the National Cancer Institute* (Gammon et al., 1998).

Even though postmenopausal women have nonfunctioning ovaries, their body fat can convert other hormones into estrogens. It appears that exogenous hormones, like endogenous hormones, can increase the risk of breast cancer, but the impact of exogenous hormones, such as those used in hormone replacement therapy or oral contraceptives, is unclear.

Dr. Gammon concluded with a discussion on the percentage of breast cancers that can be attributed to various risk factors. A study of women under age 55 shows that reproductive risk factors in this age group account for about 50 percent of the breast cancers. When medical history factors such as family history of breast cancer or benign breast disease are added, the number increases to about 55 to 57 percent, and when alcohol use, use of oral contraceptives, and large body size are added, 60 to 70 percent of all breast cancers can be explained in women under age 55 (Brinton et al., 1997). An Italian study of women of all ages that included established risk factors but not alcohol use or large body size found that these risk factors accounted for 52 to 56 percent of breast cancers (Tavani et al., 1997).

The fact that these studies leave about 30 to 50 percent of all breast cancer still unexplained indicates that other risk factors need to be examined. Researchers are exploring environmental risk factors, other lifestyle factors, height, perinatal exposure to estrogen, physical activity, and diet. Tumor markers also are being investigated; researchers are looking at BRCA1, BRCA2, and other markers of genetic susceptibility, as well as tumor characteristics, to develop early markers of breast cancer.

between radiation dose and cancer risk than any other human carcinogen, and female breast cancer come from several epidemiological studies of medically exposed populations and from studies of

Dr. Land presented the following graph (Figure 1), in which breast cancer risk among atomic mSv, or 0.005 Sv; for comparison, note that 1 mSv is the annual dose from natural background cases at each dose level is presented above or below the confidence limit. The slanting lines are

By far the largest number of survivors received doses less than 0.25 Sv, and nearly all of the 440 the dose response in the low-dose range are shown in the inset graph. As can be judged from the consistent with the fitted dose-response curve, but a dose-response curve based only on the data about the relationship between radiation dose and breast cancer risk. This, in a nutshell, illustrates low-dose data. If we had only data on risk below 0.10 Sv, we would not have any reason, from pattern, however, is so consistent internally that it is scientifically reasonable to conclude that

Another characteristic of radiation-related breast cancer is that exposure at young ages is illustrated by the next graph, which shows the slopes, and their confidence limits, of fitted, linear older (horizontal lines) and at ages 0-4, 5-9, ... , 50-54, and 55 or older (points with vertical with increasing age at exposure; also, however, there is statistically more variation among the three years of age than at older ages, but it is not clear that exposure before age 10 is more dangerous

Another important consideration is how radiation-related excess breast cancer risk varies over time, or with increasing age, following exposure. The next graph plots dose-specific excess relative risk by attained age, for women exposed at 0-19, 20-39, and 40 years of age or older. Several patterns emerge: As expected, the range of attained ages for which we have information varies by age at exposure. For any particular age at diagnosis, dose-related excess risk decreases with increasing age at exposure, echoing the evidence of Figure 2. For cancers diagnosed after about age 35, there is little variation, for a specific age at exposure, in dose-specific risk by age at diagnosis. Thus, radiation-related excess relative risk depends upon age at exposure, but otherwise (after age 35) doesn't depend upon age at diagnosis. In other words, for any given age at exposure, the dose-related excess breast cancer *rate* is a fairly constant multiple of the baseline (zero-dose) breast cancer rate as it varies by age at diagnosis.

Finally, there is one anomaly; the dose-specific excess relative risk was very high for early-onset breast cancer, at least among women exposed before 20 years of age. We know that women with germline mutations in the BRCA-1 gene, for example, have substantially increased lifetime risk of breast cancer, and that their risk of early-onset breast cancer is especially high. Dr. Land hypothesized that the anomaly, observed in Figure 3, might indicate a genetic predisposition, in some so-far undefined population subgroup, to environmental mammary carcinogens in general and ionizing radiation in particular.

Following up on Dr. Gammon's comparison between breast cancer rates in the United States with those in Japan, which are several times lower, Dr. Land noted that there are enough data on medically-irradiated populations in the United States and Canada to make direct comparisons between the two populations. North American patterns of dose-specific excess relative risk are similar to those seen in the Japanese atomic bomb survivors, but the North American data give lower overall relative risks. However, excess *rates* are similar, i.e., the same amount of radiation appears to cause the same amount of risk, in absolute terms, in Japanese and North American populations. Thus, whatever causes breast cancer rates in the United States to be four times higher than those in Japan does not appear to interact markedly with ionizing radiation.

As covered in Dr. Gammon's presentation, reproductive history is strongly related to breast cancer risk; for example, it has been demonstrated in several different populations that having a first full-term pregnancy at a relatively young age is associated with lower breast cancer rates than are observed among nulliparous women and among those whose first pregnancy occurred at an older age. The same pattern was shown to hold in A-bomb survivor population. Also there was a synergistic effect between this variable and radiation dose: women who experienced an early first full-term pregnancy appeared to be protected to roughly the same extent against both baseline and radiation-related breast cancer risk. Remarkably, the protective association against radiation-related risk was observed among women who were exposed as children as well as among those exposed as adults. This result is in agreement with experimental studies conducted in the 1970s by

Clifton and Crowley showing that terminal end bud differentiation of mammary tissue cells, which

even if it already has received damage that would predispose it to breast cancer.

In conclusion, Dr. Land commented that we know that ionizing radiation exposure can cause

dose reduces radiation-related breast cancer risk; theoretically, for any pre-set level of risk, there is a dose level below which that risk level is not exceeded.

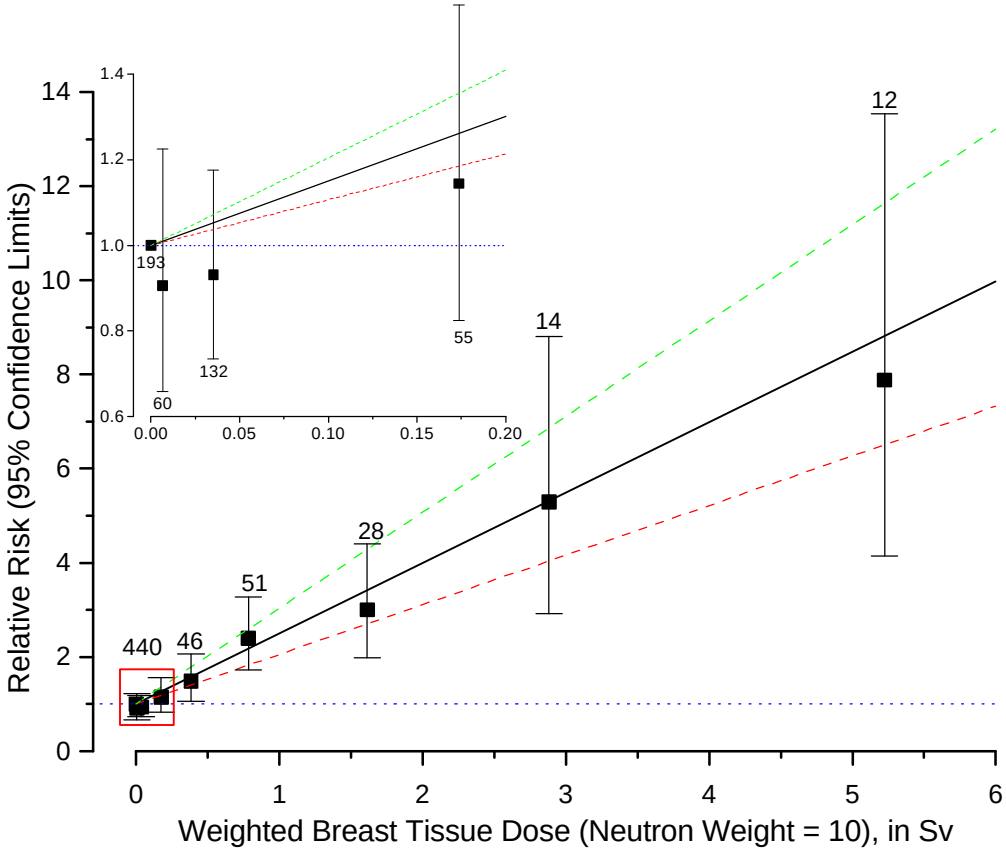

Figure 1. Radiation dose response for breast cancer incidence among atomic bomb survivors. The inset corresponds to the box at the lower left-hand corner of the main graph, giving details at low doses.

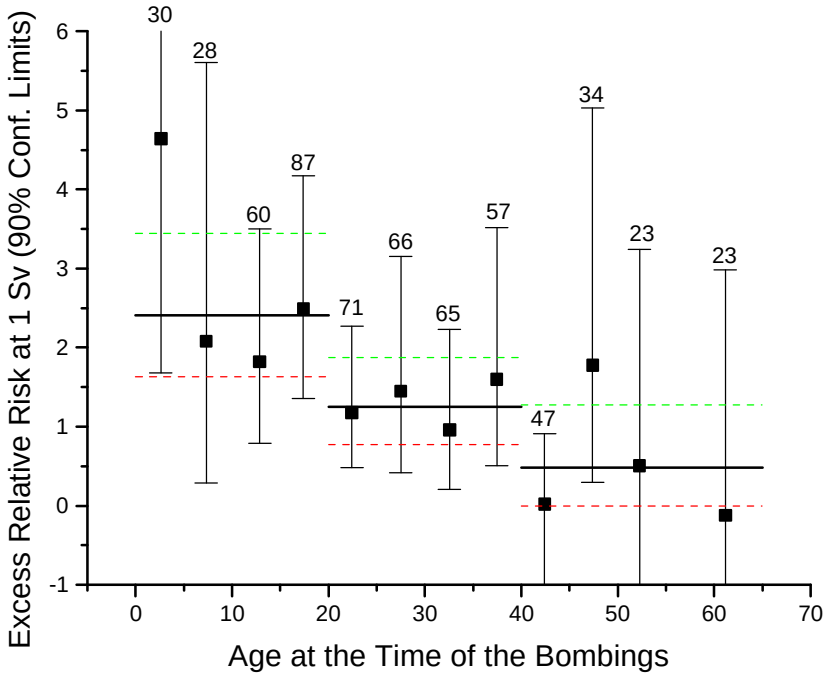

Figure 2. Variation in dose-specific excess relative risk by age at exposure. Numbers of cases are given above each data point.

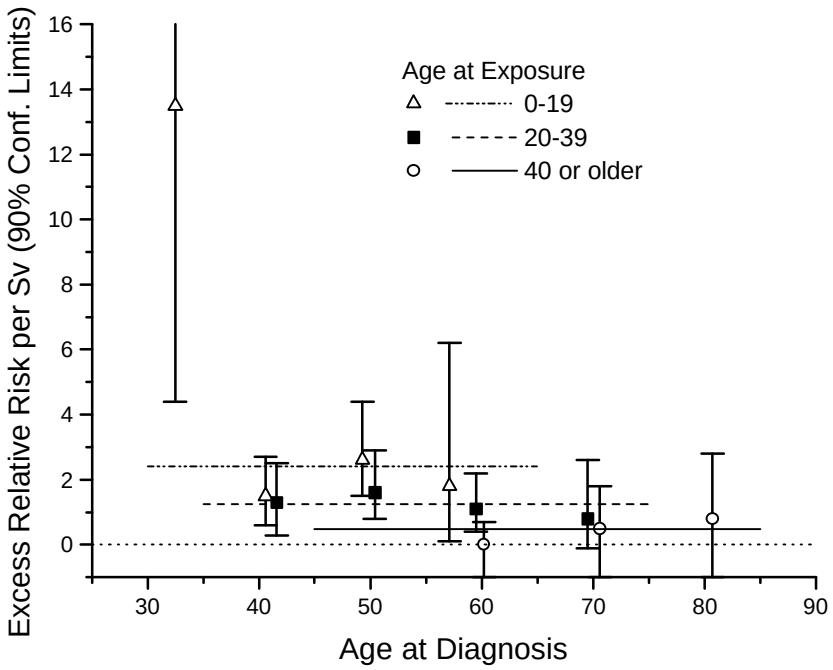

Figure 3. Dose-specific excess relative risk of breast cancer, by age at diagnosis within intervals of age at exposure.

GENETIC SUSCEPTIBILITY TO RADIATION-RELATED BREAST CANCER
Michael Swift

Ionizing radiation is the only environmental agent proven to induce breast cancer. The ataxia telangiectasia (AT) gene, present in many ethnic groups, is the best established radiation-sensitivity gene. About 1.4 percent of the population carry this gene. However, the occurrence of two copies of the AT gene is rare. Homozygotes, or individuals with two copies of the gene, exhibit a multisystem disorder with neurological disease and immunological problems, are at high risk for cancer, and are highly sensitive to IR, both clinically and in the laboratory. Unlike AT homozygotes, AT heterozygotes appear clinically normal. AT heterozygous individuals do not have the rare AT disease but are carriers of the gene; they have a fourfold excess breast cancer risk and an elevated sensitivity to radiation in the laboratory. It is not yet possible to identify AT carriers in the general population, but Dr. Swift has been able to learn about them by studying the extended families of AT homozygous individuals. Dr. Swift commented that a test for the AT homozygote is not needed, because the condition can be diagnosed clinically. However, he currently is working on a heterozygote test similar to the BRCA1 test in which exons (sequences of DNA that are expressed as all or part of the polypeptide chain of a protein) are scanned with a sequencer, but he does not know when the test will be available for clinical practice.

Dr. Swift reviewed a series of studies from the 1970s to the 1990s that indicated an excess breast cancer risk among women who carry the AT gene (Swift et al., 1991). Dr. Swift also is involved in an ongoing study of 300 families. A study of the same age group in AT families in the 1950s through the 1980s found a rising incidence of breast cancer, suggesting the effect of an environmental factor. In the most recent study, relatives of AT families were genotyped using molecular methods; almost all of them were found to be carriers. The onset of breast cancer before age 60 had a lower odds ratio than that for onset after age 60 (Athma et al., 1996). From the 1.4 percent prevalence in the population, Dr. Swift estimated that AT heterozygotes may comprise 6.6 percent of all breast cancer cases. He also believes that mutations at the AT locus are more statistically significant than those at the BRCA1 and BRCA2 loci.

In a discussion of chronic and acute radiation exposure, Dr. Swift noted that heterozygotes and homozygotes differ in their sensitivity to radiation. AT homozygotes cannot tolerate clinical radiation exposure. It is suspected that the AT homozygous cells have a defect in cell cycle regulation that causes damage from x-rays to pass through the cell cycle unrepaired, which explains why AT homozygous individuals are extremely sensitive to IR. AT heterozygotes seem to have laboratory evidence of radiation sensitivity in their cells. There is speculation that the AT heterozygote who gets cancer is at higher risk of severe radiation reaction. Surprisingly, the data do not indicate this; clinically, these individuals have no excess risk of severe radiation reaction.

In a discussion of breast exposure to medical diagnostic x-rays, Dr. Swift commented that total lifetime dosage cannot be determined accurately. Dose is almost never measured in clinical practice, and there is extremely wide variation in the range of dose, even within the same radiology suite. Because dose cannot be determined accurately, Dr. Swift's 1991 study defined exposed women as those who had therapeutic irradiation to the chest; fluoroscopic examinations of the chest, back, or abdomen; or occupational exposure to IR. The study used a latency period of 5 years. Among breast cancer cases, 10 were exposed and 9 unexposed, and in the matched controls, 11 were exposed and 46 unexposed; the odds ratio was 5.8 that an AT relative would get breast cancer, based on exposure (Athma et al., 1996).

When the 1991 study was published, the radiobiological community responded negatively because this finding opposed the popular view that medical x-rays do not cause an excess of cancer, even in a genetically predisposed group. Dr. Swift examined the literature to identify studies that had been conducted of the general population and to determine the basis for current standards of medical safety. He found that excess breast cancer risk depends on the cumulative lifetime dose; that the risk is higher for the same dose in women exposed at a younger age; and that the doses in the early days of mammography, extending in some cases into the 1980s, were extremely high. In the 1960s and 1970s, these doses often were greater than 200 milligrays per film or per series (compared to the 1995 Food and Drug Administration [FDA] accreditation standard of less than 3 milligrays per film for the "average" breast). Studies of women exposed to the atomic bomb and of women who had been fluoroscoped found that high doses of IR led to excess breast cancer risk, but data were insufficient to draw conclusions about low doses. Dr. Swift reviewed five studies in which the excess cancer incidence after low doses of IR was measured; in these, the excess cases per million exposed women ranged from 20,000 to 170,000.

New studies are needed to test the hypothesis that increasing exposure to IR is related to excess risk. Dr. Swift suggested that future research examine ranges of doses rather than precise doses (since exact doses are difficult to obtain). Instead of using a dose-response curve, researchers should simply study whether excess risk exists and use matched controls—sisters, if possible. For example, women who had three or more fluoroscopic procedures or women who had screening mammograms with progressively decreasing doses could be compared to their unexposed sisters. Such matched control studies are practical and should be implemented immediately. In the meantime, a substantial effort must be made to minimize breast exposure for medical diagnostic x-ray procedures.

OVERVIEW OF EXPERIMENTAL RESEARCH
Robert L. Ullrich

Dr. Ullrich's experiments with mice on the effects of low-dose radiation corroborated Dr. Land's conclusion drawn from similar research with humans: it is difficult to measure directly the effects

of low doses. Even when examining the extremely large populations required to study the effects of low doses, the measurement of an effect has wide margins of error. In studying animal systems, the parameters are different from those of human studies, but questions can be asked regarding the dose-response relationship and the effect of low doses. When using animal models, it is not possible to define statistically what the dose-response curve is, but according to a particular model, certain actions should produce specific results. Otherwise, the model is incorrect. The experimental animal system can indicate what the effects are at low doses and how applicable animal data are to humans; it also provides a better understanding of the mechanisms involved.

In a review of tumor induction studies using experimental animal systems, Dr. Ullrich discussed dose-response relationships for the induction of mammary tumors in BALB/c female mice after exposure to gamma rays and neutron radiation (Ullrich, 1983). BALB/c is a strain of mice used in laboratory research that is highly sensitive to the induction of mammary tumors, ranging from a 7 to 8 percent background incidence to almost 20 percent after a dose of 25 centigray. At higher doses, this percentage increases only slightly and levels out because the mice have very sensitive ovaries and irradiating at higher doses induces premature menopause.

Dr. Ullrich also reviewed data on the effect of lowering the dose rate (Ullrich, 1984). Mice were exposed to total doses up to about 50 rads given at a very low rate—1 rad over a 24-hour period and 50 rads over 50 days. The effect was greatly reduced when the dose rate was lowered. This result is more consistent with a linear quadratic dose response, in which the dose response is linear at low doses and increases at higher doses.

This kind of dose-response curve generated specific predictions that Dr. Ullrich and his colleagues tested. They predicted that if a total dose of 25 rads were given in 5 rad fractions, there would be no fractionation effect, whereas reducing the dose to a total fraction of 1 rad would produce exactly the same effect as low-dose radiation. The result was exactly as predicted: too high a dose as a fraction is the same as an acute exposure, and a much lower dose produces a reduction in the effect (Ullrich, 1987). Dr. Ullrich also commented that the definition of low dose differs greatly for various tumors.

This animal model corresponds to breast cancer in humans in several ways: (1) the pathology looks similar; (2) all of the oncogenes and tumor suppressor genes in human breast cancer are found in these mice; and (3) the life history of the system is similar—irradiation produces tumors preceded by dysplasias similar to preneoplastic lesions in human breast cancer.

To determine how radiation eventually changes normal cells into tumors, very early radiation-altered cells had to be identified. Dr. Ullrich and his colleagues irradiated a mouse, removed the mammary tissue, made a single-cell preparation, and injected it into a 3-week-old mouse from which rudimentary mammary tissue was removed. A 3-week-old mouse was chosen because that

is the age when mammary tissue is developing. When cells were removed 24 hours after irradiation and injected in fat pads, a fraction of those fat pads looked different: ductal dysplasias appeared with the capability of expressing themselves. When the researchers examined these dysplasias as a function of time after radiation at 24 hours, 1 week, 4 weeks, and 16 weeks, they found a group of dysplasias that persisted and were unresponsive to growth regulatory mechanisms. These persistent dysplasias subsequently formed tumors (Ullrich, 1996).

When altered cells induced by radiation were measured, the differences between mouse and human cells in mammary glands were small. The researchers measured the effect of lowering dose rate on the frequency of ductal dysplasias and found that lowering the dose rate of gamma rays decreased the effectiveness of inducing these initiated cells. They also examined dysplasias initiated by chemical carcinogens, followed by radiation exposure, and were unable to demonstrate that radiation had any influence on enhancing expression. The conclusion was that radiation initiates altered cells but does not influence progression of these cells to tumors.

Dr. Ullrich believes that radiation induces an instability in cells that eventually results in the formation of mutations. Using genetic models, he has found differences in mice in the sensitivity of cells to the induction or initiation of dysplasias. Studies of mice indicate that there are unidentified cellular factors associated with breast cancer susceptibility, and Dr. Ullrich hypothesized that some mice may have a cancer susceptibility gene associated with mammary tumors. This animal system also could be used for further research on genes that are known to be related to breast cancer, such as the BRCA and AT genes.

RADIATION PROTECTION IN MEDICAL RADIOGRAPHY AND BREAST CANCER
Fred A. Mettler, Jr.

Dr. Mettler noted that the first papers indicating that radiation causes breast cancer were published about 30 years ago. In 1996, the International Commission on Radiological Protection (ICRP) published "Radiological Protection and Safety in Medicine," which addresses how radiation protection should be applied in medicine and provides basic concepts for diagnostic radiology and other areas such as nuclear medicine and radiotherapy. Dr. Mettler, who is chair of the ICRP committee on medicine, explained that the committee's objective is to determine how radiation protection issues should be applied in medicine. Committee members represent many countries, including the United States, and a variety of disciplines, such as mammography, general diagnostics, pediatric radiology, and nuclear medicine.

In the ICRP approach to radiation protection in medicine, the first step is to determine if a practice, such as mammography, can be justified: the practice as a whole should do more good than harm. In addition, a practice should be justified for a particular individual. Nonionizing

radiation techniques also must be considered, such as substituting an ultrasound for a mammogram if the same effects can be obtained.

Once a practice is found justifiable, the next step is "optimization," or developing methods to improve the practice. Optimization in radiation protection often means taking steps to keep the dose as low as possible. The objective—to attain the greatest benefit with the least amount of risk—can be reached through such techniques as faster film and fewer x-ray views.

Medicine is the largest contributor to man-made radiation exposure. Nothing can be done to reduce approximately three-quarters of the total radiation to which we are exposed, but exposure to excess radiation through diagnostic x-rays and nuclear medicine can be reduced. The question of dose limits is raised continually. Obviously, higher doses of radiation than necessary are not desirable, but most people do not realize that, in radiology, a clear X-ray film may not be obtained if the dose is too low. Thus, the radiation may simply be wasted, with no benefit to weigh against the possibility of risk, however small. There is wide variation in dose in radiological procedures throughout the world. The instinct of many researchers, health care practitioners, and consumers is to establish a "correct dose" (e.g., to establish that the correct dose for a chest x-ray is 15 millirads). However, establishing a correct dose is not easy, because dose is dependent on the patient's size and, in mammography, the density of the breast. Rather than focusing only on establishing a correct dose, it is more beneficial to focus also on reducing dose by shielding other parts of the body and by eliminating unnecessary x-rays.

Factors in radiology practice that influence or can reduce dose include elimination of unnecessary exams (which sometimes is related to the availability of previous films), fluoroscopy time, quality assurance, collimation, shielding, and compression of the breast. In mammography, the kind of target in the machine and filtration affect dose. Equipment-related issues affecting dose include film-screen combination, use of intensifying screens, position of the patient, antiscatter grids, and film processing.

There are dose limits for radiology technicians but not for patients. In treating patients, practitioners need to consider the procedures they are using, the level of the dose, potential harm and benefits, and the risk/benefit ratio. In general, worldwide dose limits for particular x-ray procedures are not being proposed, but there is interest in establishing reference levels. Diagnostic reference levels should be made with regard to national or regional information and available resources. For example, a reference level set in the United States would not be applicable in India or China. Reference levels, which apply to common exams with a standard phantom, change over time due to changes in technology. Dr. Mettler commented that it is the responsibility of institutions to train and educate their staffs. For example, in Dr. Mettler's hospital, it is mandatory for anyone operating radiology equipment, including physicians and radiologists, to attend a 1-hour lecture and pass a written test every year. Health care practitioners have a personal interest in

reducing radiation exposure, because the scatter from patients' x-rays could affect them. Radiation protection ultimately requires balancing medical necessity (which is extremely difficult to define), costs and benefits, and available equipment.

To help meet the worldwide need to educate medical students about medical radiation protection, the ICRP is working on a general document for medical students. To reach doctors, the best approach is to target doctors in a specific area and create user-friendly documents. A large number of x-ray procedures are not done by radiologists but by surgeons, internal medicine physicians, cardiologists, and orthopedists. Dr. Mettler is especially concerned about pediatric films and the use of fluoroscopy by cardiologists. In most states, no training is required to use the fluoroscope, which generates the highest dose, and no certification is required beyond being a licensed health care practitioner.

Dr. Mettler also mentioned "Mammography: A User's Guide," published by the National Council on Radiation Protection and Measurements, which has a committee on medicine that includes representatives from the disciplines of mammography, ultrasound, interventional therapies, and nuclear medicine, which encompasses radiation therapy.

MAMMOGRAPHY: WHAT HAS BEEN DONE AND HOW IT WAS DONE (Experience from the Food and Drug Administration with the Mammography Quality Standards Act)

The FDA's Experience with Mammography
Florence Houn

The Food and Drug Administration has been involved with dose and image quality in mammography for many years. The first mammography case was brought to the attention of FDA staff members in the early 1970s when they worked with a facility in Pennsylvania to address dose in a 50-rad exposure. In the 1980s, several surveys of mammography facilities indicated a problem in image quality. Congress passed the Mammography Quality Standards Act (MQSA) in 1992 in response to lobbying by the FDA, the American College of Radiology, other professional societies, and consumer advocates. The act requires that every mammography facility be certified by the FDA, undergo accreditation (i.e., the facility's clinical images must be examined, evaluated, and passed in terms of quality), undergo an annual inspection, and conduct an annual physics survey. In addition, all mammography facility staff members must meet personnel qualifications, and every facility must meet Federal standards for recordkeeping, reporting, quality assurance programs, quality control activities, equipment requirements, and dose. Currently, the Federal dose limit in mammography is 300 millirads.

The FDA has inspected every mammography facility in the United States twice, and approximately 30 percent have undergone a third inspection. The average dose in U.S. facilities is approximately 150 to 160 millirads.

The Federal response to mammography arose from consumer and professional concern about image quality, dose, and accuracy. The FDA has set a baseline standard for quality and for dose, thereby giving women confidence in their mammography facilities. Presently, the MQSA is undergoing reauthorization by Congress. The act has established a precedent in requiring one area of medicine—the practice of mammography—to provide a reliable, high-quality test for a life-threatening disease. Although it is not perfect, mammography is the best available method for the early detection of breast cancer.

The FDA's Work in Mammography: Image Quality and Dose
Orhan H. Suleiman

Dr. Suleiman noted that dosimetry in epidemiological studies is still an art rather than a science. However, the FDA brings a level of accuracy and precision in its dose estimates in mammography. Each mammography facility that the FDA inspects is given a printout of the dose measured at that facility using a standard methodology, enabling a comparison to information from other facilities throughout the country.

Mammography is much more standardized than any other area of image quality radiography. The FDA has standardized mammography by examining phantom quality, which is the standard method of looking at film; the FDA also examines the x-ray equipment and the film processor. In 1985, the Nationwide Evaluation of X-ray Trends (NEXT) survey program conducted a survey of mammography facilities by taking pictures with a standard phantom and measured dose. In 1986, the American College of Radiology developed its own Mammography Accreditation Program and adopted the NEXT physics protocol for mammography, thereby developing a standard methodology for all facilities.

The approximately 50-fold reduction in radiation exposure from the 1970s to the 1990s is consistent with the conversion from the use of direct film to the use of an intensifying screen with film prevalent in mammography today. With direct film, the image quality, specifically spatial resolution, is superior to that of screened film, but the dose is much higher. In the early 1970s, two-thirds of mammograms were obtained with direct film, but today mammography is essentially a screened-film technology. Dental x-rays still use direct film, but even in dental radiography, doses have been significantly reduced.

Dr. Suleiman showed a series of films comparing different radiographic technologies used on the same patient over several years: direct film radiography in 1969 with the patient receiving a dose of

1,600 millirads; 6 years later, the first of the screened-film technologies, with a fivefold to sixfold reduction in dose; xerox radiography; screened-film mammography in 1983; and finally, in 1992, extended cycle processing, which reduces the dose to about 8 millirads.

Dose cannot be assessed without understanding image quality. Important attributes of image quality include detail, contrast, and noise (i.e., background graininess against which the signal must be seen). If dose is reduced, the noise in images increases, resulting in reduced image quality. Because the optical density at which the mammogram is viewed may affect other image quality attributes, higher density may be preferable, or the optical density may need to be matched with a very specific type of film. However, as the optical density is increased, the dose must be increased. Image quality continues to improve, but Dr. Suleiman is concerned that some facilities may be reducing dose to the detriment of image quality.

Radiography is moving toward digital or filmless imaging, a technology with many advantages but also with potential for problems. One of its advantages is that the need for multiple views can be eliminated because different views can be reconstructed from one exposure. Also, the contrast and latitude can be enhanced by changing the contrast control, and the digital images can be used for computer-assisted diagnosis. The technology also has the potential for lower dose. Digital imaging is more user friendly, which is both an advantage and a disadvantage, because it can result in more images being taken. In addition, there is a risk for higher dose if the technician does not know what dose is being delivered. Thus, there is the potential for higher dose not only per image but cumulatively as well. Mammography as a screened-film imaging procedure currently is relatively inexpensive; digital technology is more expensive. The higher expense may slow the use of this technology as a screening modality.

The MQSA established by legal mandate specific performance measures. The FDA's experience with the NEXT program and the MQSA shows that an acceptable range of radiation doses can be established as long as those limits are not too restrictive and they are periodically evaluated and adjusted. Dr. Suleiman concluded that mammography today, in spite of subtle increases in dose in the past few years, provides better image quality at lower doses than ever before.

LEGAL ISSUES
Janice Platner

Dr. Platner, who was diagnosed with multiple myeloma in 1985 when she was 35 years old, remarked that radiology technicians tend to get myeloma. When thinking about legal issues, it is important to consider what a particular legal action will mean in the real world. It also is necessary to identify objectives and procedures for reaching them. For example, if education is an objective in addressing individual or cumulative exposure, guidelines or regulations could have educational

value for clinicians, providers, and, hopefully, the public. If setting a limit on individual and cumulative exposures is another objective, procedures for accomplishing this outcome must be developed. Finally, if accountability is an objective, it is necessary to identify who should be held accountable for the types of exposure people are getting from medical x-rays and from cumulative exposure.

Because mammography is a procedure that uses particular equipment for a specific purpose, it is easier to regulate than other medical radiation procedures. Few regulations governed mammography's use until the implementation of the MQSA. Dr. Platner also commented that, in some cases, regulations may act as more effective controls than statutes because they can be changed and amended more easily.

Another issue is compliance. In setting standards, whether they are regulations or guidelines, it is necessary to consider who would monitor compliance, how it would be measured, and how and by whom it would be enforced. Another consideration is whether regulations would pertain to all health care staff who administer x-rays, such as radiologists, other physicians, technicians, chiropractors, and dentists, and what the regulations would mean for each of these groups.

Dr. Platner then discussed consumer-based issues, starting with disclosure. Questions to consider on this topic include whether disclosure is preferable to regulation, what information would be disclosed to consumers and who would make this decision, and whether disclosure by itself is adequate. If informed consent is desired in addition to disclosure, the questions include whether informed consent should be required, what constitutes meaningful informed consent, and who would be asked to give informed consent and when.

The issues surrounding confidentiality of medical records include informed consent and accountability. Dr. Platner commented that the number of people in addition to physicians who have access to records is growing, and she questioned whether it is desirable for so many people to have access to such information.

Another issue is the practical aspect of what regulations would mean in the daily clinical practice of medicine. For a long time, medicine was practiced with a "better safe than sorry" approach, resulting in overtesting and overtreating. With managed care limiting the use of tests, the questions now concern who decides when tests should be used and how to obtain the best care for a particular patient.

Finally, Dr. Platner raised questions about malpractice, product liability, and negligence regarding lifelong exposure. For example, if guidelines are established and a physician, believing that the benefit of an additional x-ray or treatment far outweighs the risk, violates those guidelines, would

that physician be liable for a malpractice or negligence suit? Although consumers tend to dismiss such issues, they are important in the clinical practice of medicine.

DISCUSSION AND QUESTIONS FROM THE AUDIENCE
Shirley A. Fry, Moderator and Rappoteur

Several workshop discussion sessions offered participants the opportunity to ask questions of the speakers and share information and comments. The following is a summary of those discussion sessions.

Review of Presentations

Dr. Fry summarized the workshop presentations before inviting comments from the panel and members of the audience. As the presenters indicated, progress has been made in educating the public about IR as a risk factor and in understanding IR's role in the diagnosis and treatment of breast cancer; however, substantial gaps remain in these areas and in the understanding of breast cancer in general. Of particular concern is the drastic decline in recent years of financial support for experimental studies of radiation carcinogenesis, which remains the only way of answering certain questions that emerge from epidemiological and molecular investigations. More work is needed to facilitate the development of new and improved modalities for screening, diagnosis, and treatment that can increase the benefits of medical IR while minimizing risks. The presentations also demonstrated the need for improved communication and education among all parties—patients, the public, researchers, medical practitioners, and expert advisory groups—involved in issues relating to medical radiation and breast cancer.

Dr. Fry concluded that this workshop represents a major step in bridging both scientific and humanitarian gaps by bringing all of the parties to the table as equal partners in the effort to prevent or minimize the risk of breast cancer among women of all ages.

Research Issues

<u>Mammography Studies</u>

A participant asked whether several large, randomized mammography studies conducted in Sweden, Great Britain, and the United States would be helpful resources in estimating the human health effects of exposure to low doses of IR. The comment was made that these studies or any randomized studies are not the setting in which the effects of exposure to low doses of IR can be addressed because any screening test or early detection tool will detect cases of cancer that would

not have been diagnosed without the test. Depending on the level of overdiagnosis, it can remove any ability to detect cancers that might have been caused by IR.

Dr. Swift noted that Scandinavian studies published in the 1980s showed a small but not particularly significant excess of deaths from breast cancer in screened women; one popular explanation was that radiation was inducing or accelerating breast cancer. In the Scandinavian and U.S. mammography studies, the matching was simply for randomization, which is an effective procedure. Demonstrating effects of modest size, however, calls for the best possible matching, which these studies did not have.

Dr. Suleiman mentioned that, when looking at mammography studies over time, one must consider that the quality of mammography has improved dramatically.

Research on Atomic Bomb Radiation

A participant commented that gamma rays from atomic bomb radiation are half as effective in causing cancer as medical radiation. Therefore, the 26.3 percent of all breast cancers in the atomic bomb study up to 1985 would be analogous to 52 percent of breast cancers caused by medical radiation because of the difference in the effect of medical radiation and gamma rays. This is close to John Gofman's estimate of 75 percent of all breast cancers being caused by radiation given from 1920 to 1960. Dr. Land expressed uncertainty as to how these figures were derived because the doses Dr. Gofman was referring to are different from the average doses received by atomic bomb survivors.

Research on the Interaction Between IR and Other Carcinogens

A participant suggested that, in examining the cumulative effects of radiation on the development of breast cancer, research also must consider the cumulative effects of environmental carcinogens, carcinogens in food, and other risk factors, all of which may interact to increase risk.

In response to a suggestion to examine the interaction of smoking and medical IR, Dr. Land explained that research has been done on their interaction in the development of lung cancer. Before studying their interaction in the development of breast cancer, however, the relationship between smoking and breast cancer must be established.

Dose Issues

Low-Dose Radiation and Breast Cancer

An advocate read a letter to *Lancet* from Dr. Gofman asserting that women exposed to low levels of radiation have excess rates of breast cancer and that even low doses are carcinogenic. Dr. Ullrich agreed that low doses of radiation are potentially carcinogenic to the breast and commented that the definition of "low dose" should be considered carefully for each tumor type. The definition of low dose for breast tissue, the tissue most sensitive to x-ray exposure, is less than 2 rads.

Effects of Cumulative Mammographic Exposures

One participant commented that efforts to determine and minimize doses have focused on the per mammogram radiation dose. However, the role of the health care provider in cumulative dose also should be considered. For example, some health care providers are conservative about calling for x-rays. Although the doses from mammography per view are relatively safe, Dr. Suleiman said, the cumulative dose from mammography and other radiographic procedures may be cause for concern.

A participant asked how the idea of "safe" levels of IR could be defended, especially in regard to multiple exposures, when even low doses can be harmful. She recommended that participants come to consensus about the risks so they can take steps to reduce them, such as educating the public.

Dr. Land replied that there is no "safe" level of exposure, only levels ranging from low to high risk. Instead of identifying safe levels, experts must devise a strategy to achieve the greatest benefit while accepting the least risk. Such a strategy may involve eliminating unnecessary exposures and, when exposure is necessary, using the lowest doses possible that consistently have demonstrated benefit.

Probabilistic and Deterministic Dose Effects

A participant commented that in connection with low dose, less than 15 centigrays, IR effects can be of two types: probabilistic and deterministic. The probabilistic effects for cancer induction have a dose response of about 15 centigrays. However, in the lower dose region, it is debatable whether the dose response is linear or linear quadratic. For deterministic effects, there is a dose response, but there also is a threshold for that type of effect.

Other Possible Carcinogens

In answer to a question about computers as a source of radiation, Dr. Suleiman noted that computers do not emit IR but rather produce electromagnetic fields. The Radiation Control for Health and Safety Act, which was passed in 1968 in response to concern about emissions from

color televisions and microwaves, gave the FDA the responsibility of protecting the public from electronic products that emit radiation. Dr. Suleiman is the executive secretary for the FDA Advisory Committee on Electronic Product Emissions, which will be considering fluoroscopes, mammography equipment, and televisions at its next meeting.

Suggestions for Consideration

One participant expressed the need for consensus among members of the medical community that both low- and high-dose IR can damage tissue and cause cancer.

A few participants stated that research should continue to improve mammography—currently the only diagnostic tool for detecting breast cancer—but suggested developing methods that do not use ionizing radiation (e.g., blood tests).

Another suggestion voiced by several participants was the need for education, especially within the medical community, about the risks of high- and low-dose radiation. Specifically, physicians should know the risks of radiation exposures in young women, the cumulative effects of radiation procedures, and the standards for exposure for the general public and for those who are exposed occupationally.

Other suggestions included convening a workshop on exposure to IR from fallout caused by atomic bomb testing and from nuclear power plants, giving patients copies of exact measurements of their IR exposures and encouraging them to track exposures, and issuing a statement on behalf of the workshop participants acknowledging IR as a risk factor and describing its effects.

Developing Standards and Policies

When asked how safe dose limits were established by the NCRP, Dr. Suleiman answered that educated consensus has determined the safe dose level. When the NCRP first established a safe dose in the mid-1980s, there was no standard method to assess dose, but professionals could estimate the doses that women were receiving. Experts on the advisory panel arrived at the consensus that safe dose should be lower than 400 millirads or in the general area of 300 to 400 millirads. The panel later lowered the standard to 300 millirads.

Participants made a few suggestions for setting standards in the future. One recommended setting standards for cumulative exposures within a specific period of time (e.g., within a year), specifying a maximum number as an average. This guideline can be useful, for example, because many women have a series of mammograms to locate a tumor detected manually. Another participant stated that recommendations for specific dose levels and exposure limits should take

environmentally sensitive subgroups into consideration. Estimating the risks for these subgroups, however, is difficult statistically because they represent such a small percentage of the population.

Participants also commented on the need to make policy decisions based on credible science and peer review, and they discussed the political nature of the peer review process in the United States. Participants concurred that consumer advocates are needed on peer review and advisory committees.

ROUNDTABLE DISCUSSION: COMMENTS AND SUGGESTIONS
Barbara Balaban, Moderator

The roundtable discussion section reflects comments from individuals and does not constitute a policy position of the NAPBC or a consensus of the workshop participants. All participants agreed that the medical use of radiation is an immediately addressable, preventable cause of breast cancer. Ionizing radiation causes cancer, including breast cancer, and medical radiation has both risks and benefits. Participants made more specific comments under the following categories:

Education

There is a need to educate physicians, other health professionals, medical students, and the general public about the fact that radiation causes cancer, including breast cancer.

<u>Education of Physicians, Other Health Professionals, and Medical Students</u>

A core curriculum is needed to educate physicians, other health professionals (especially nurses), and medical students in the following areas:

Risks and Advantages of Radiation

- The dangers of all forms of diagnostic and therapeutic radiation. Because mammograms account for only a small percentage of x-rays, the breast cancer risk associated with all radiological procedures should be examined. Specifically, education should include:

  — The cumulative risk of x-rays—the effects of lifetime exposure to radiation for the entire population of women, starting from the prenatal stage.

  — DNA damage from medical x-rays, including the need for consensus on a definition of genetic damage.

- The sensitivity of the breast to radiation (the breast is among the most sensitive organs in the body and thus more sensitive to radiation). In addition, health professionals should be aware of the existence of groups that are at increased risk of damage from radiation, including young women and sensitive populations (emerging science provides evidence for high-risk groups that have an increased sensitivity to radiation).

- The concepts of carcinogenesis and cancer models.

- The advantages of all diagnostic and therapeutic radiation, including but not limited to mammography.

Prudent Use of Radiation

- The need to exercise prudent use of x-rays, fluoroscopy, and other radiologic procedures through careful assessment of each patient and adoption of effective safety measures.

    — The variation in appropriate radiation dose (the dose varies according to the patient's size and breast density). The prescribed radiation dose should be at the lowest possible exposure. In addition, there should be some consideration of doses for high-risk groups (such as individuals with AT gene mutations).

    — The importance of providing shields to protect patients from diffuse emissions from radiation to other parts of the body (e.g., shield women's breasts when they are having radiological procedures targeting their abdomen).

    — The need for certification and continuing education for individuals operating x-ray and fluoroscopy equipment and for recommendations on IR procedures.

- The need to document the frequency of radiation exposures and dosage.

- The need to achieve a balance in risk assessment (achieving an accurate risk assessment without unnecessarily alarming patients).

<u>Public Education</u>

Culturally relevant and sensitive public education is needed on a variety of subjects, including the following topics:

- The risks and benefits of medical IR, including the fact that radiation exposure is cumulative over a lifetime.

- Strategies for making informed choices about x-rays and other radiological procedures.
- The research indicating that radiation is a known cause of cancer.
- The distinction between ultraviolet rays and IR (exposure to radiation is not comparable to exposure to the sun).
- The advantages and disadvantages of computerized versus digital mammography (computerized mammography involves greater IR exposure).
- The importance of patients knowing their dose of radiation exposure (patients' medical records should include measured, not calculated, doses of radiation they receive for radiological procedures).

Strategies for addressing public education needs include the following:

- Developing a smart card (the size of a credit card) or personal dosimeter containing a patient's radiation history.
- Developing booklets or pamphlets that suggest questions for consumers to ask and guidelines for them to use when considering radiological procedures.
- Developing an 8½" x 11" fact sheet about the human body showing areas that are sensitive to IR and an explanation of DNA, the cell cycle, and a molecular biological model.
- Developing literature on informed consent (before consenting to radiological procedures, patients have a right to information about the risks of IR).
- Educating parents about IR in an effort to prevent unnecessary exposure of children to IR.
- Introducing information about IR exposure into high school curriculums.
- Developing a summary of what is known about breast cancer and radiation.
- Developing a booklet or pamphlet for consumers with basic information about medical ionizing radiation.

Research

Advocates should be involved in developing proposals and should be represented on study sections and panels. Suggested future research activities include the following:

- Development of other nonradiologic diagnostic tools as alternatives to IR mammography.
- Identification of high-risk groups (emerging science provides evidence of high-risk groups that have an increased sensitivity to radiation).
- Determination of minimum standards for acceptable lifetime exposure.
- Determination of the effectiveness of clinical exams versus mammography.
- Determination of the advantages and disadvantages of computerized versus digital mammography.
- Followup studies of (1) women treated by lumpectomy and intensive radiation, (2) newborn intensive care unit patients who have been irradiated, (3) cardiac catheterization patients, and (4) patients who received gastrointestinal fluoroscopic examinations.
- Development of a test for the AT heterozygote, development of drugs based on the AT metabolic error, and a study of its mechanisms and how to prevent them.
- A study on the effects of environment-IR interactions to determine whether they cause mutations.
- A study of drug-IR interaction effects, including chemotherapy.
- Development of a followup procedure for all radiological exposures.
- Determination of medically necessary radiation exposure.
- Studies of the effects of occupational exposure to IR (e.g., exposure of flight attendants, radiation technicians, teachers).
- Animal and molecular studies aimed at the mechanism of IR induction of breast cancer.
- A demonstration project to explore methods of improving the practice of radiology.
- A survey of radiologists to identify procedures that should be improved.

- Development of sensitive methods or assays to measure lifetime radiation exposure.
- A retrospective study of women age 50 to determine their lifetime IR exposures.
- A followup study on Dr. Gofman's demonstration project regarding medical IR as a cause of breast cancer.

Policy

Policy recommendations included the following:

- Advocate for Congress to reauthorize funding for the MQSA and allocate funds.
- Create a Federal fluoroscopy education and certification act modeled on current California law (education and discussion about this legislation also could help educate the public).
- Increase the number of IR researchers and the number of people involved in radiation protection.
- Advocate for the right to meaningful and timely informed consent for patients undergoing radiological procedures.
- Consider advocating the creation of a radiation protection act or radiation quality assurance act (examine the 1968 law to determine whether that law would be effective if enforced, or examine the MQSA as a model).
- Increase the access to and inclusion in grant and manuscript peer review processes for advocates and independent scientists.
- Advocate for the National Cancer Institute and cancer organizations to draft a joint statement that ionizing radiation causes cancer.

Additional Comments

- The final report of the IR workshop should be distributed to the media and posted on the NAPBC Web site.
- Manufacturers should be informed that x-ray equipment and other radiation equipment should show the dose patients receive at various points of exposure, taking into account that dosage actually received by patients varies due to different body size or breast density.

Target Groups

Groups targeted to receive information and recommendations related to IR include the following:

- Doctors, medical students, and other health professionals.
- Public health educators, including medical school deans.
- The general public.
- Government agencies (e.g., the National Cancer Institute).
- The media.
- Professional associations (e.g., the American Public Health Association, the American Medical Association).
- Advocacy groups.
- Manufacturers.
- Legislators.

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